

Overview of Concentrating Solar Power Technologies

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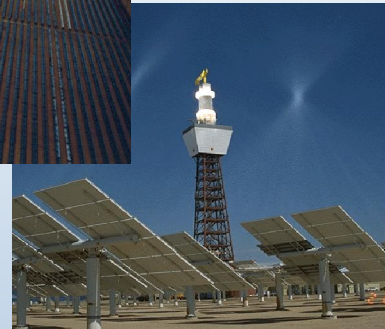
June 21, 2007

Presentation Outline

- CSP Technology Overview
- U.S./International CSP Projects and Industry
- GIS Analysis - CSP Siting and Transmission
- Power Plant and CSP Economics

CSP Technologies and Market Sectors

- Dispatchable Central Station Power
 - Parabolic trough
 - Power tower
- Non-Dispatchable Central Station or Distributed Power
 - Dish/Engine
 - Concentrating PV



CSP Systems

This film clip shows

- The Solar Two Power Tower experiment at Barstow, CA
- The Solar Energy Generating Systems (SEGS) at Kramer Junction, CA
- Two Stirling Energy Systems 10 kW Dish Stirling systems operating in Albuquerque, NM



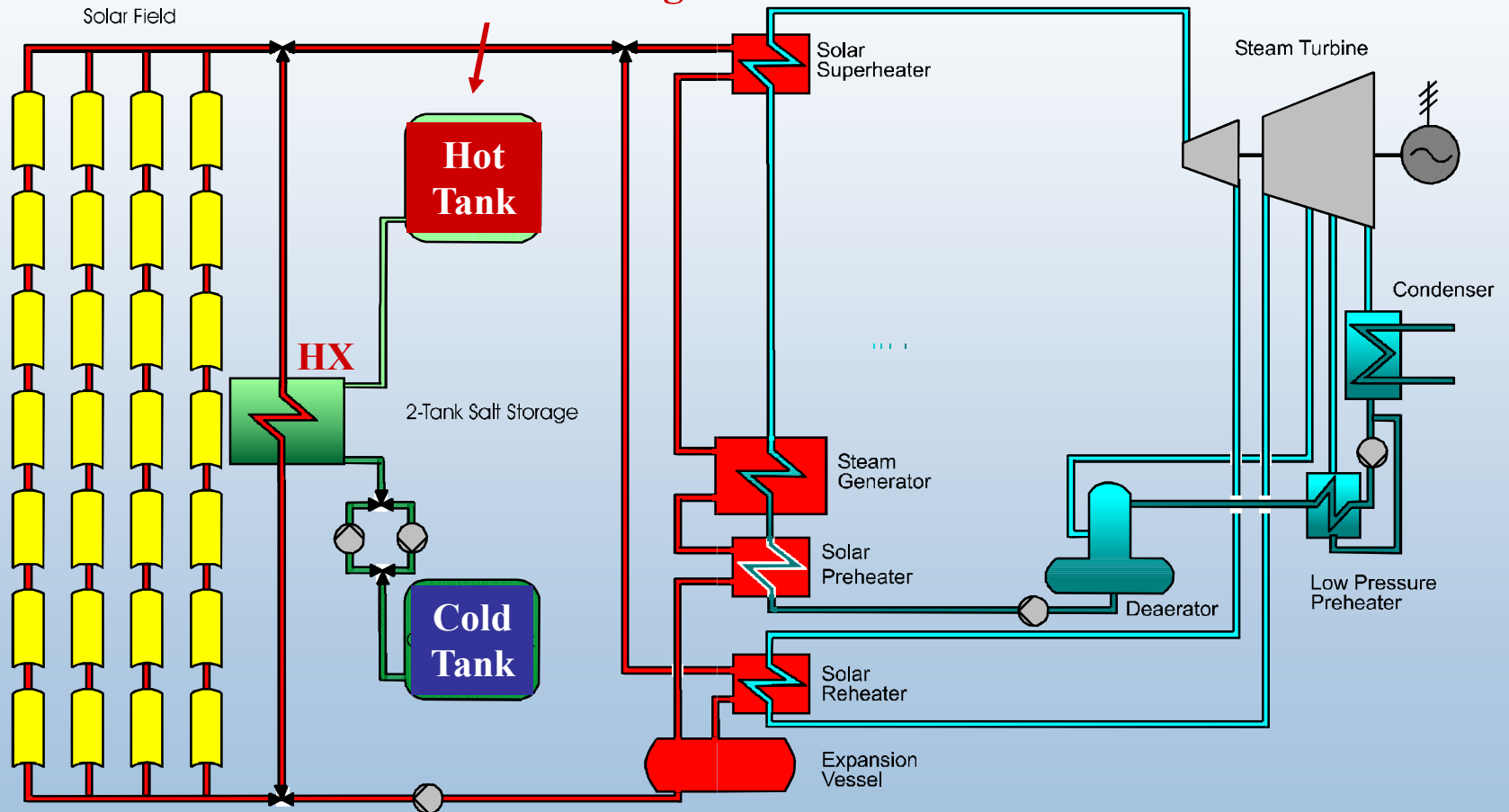
Operating Central Station Systems

- **The Solar Energy Generating Systems (SEGS) at Kramer Junction, CA (SEGS III-VII)**
 - Five 30MW hybrid trough plants for a total of 150MW Capacity
 - Commissioned 1986-1988
 - Performance has increased with time
- Four additional SEGS plants located in two locations (Daggett, Harper Lake) for combined total of nine plants and 354 MW capacity

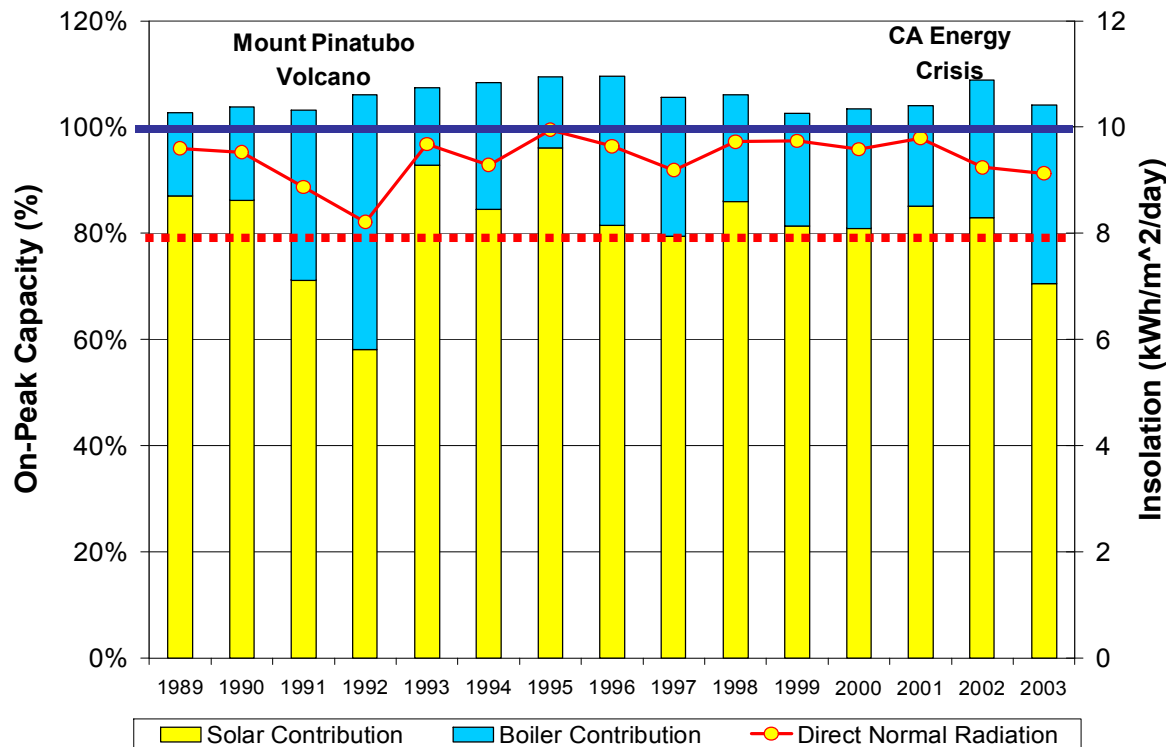


Parabolic Trough Power Plant with Thermal Storage

2-Tank Molten-Salt Thermal Storage



Historical On-Peak Performance For 5 Parabolic Trough Plants

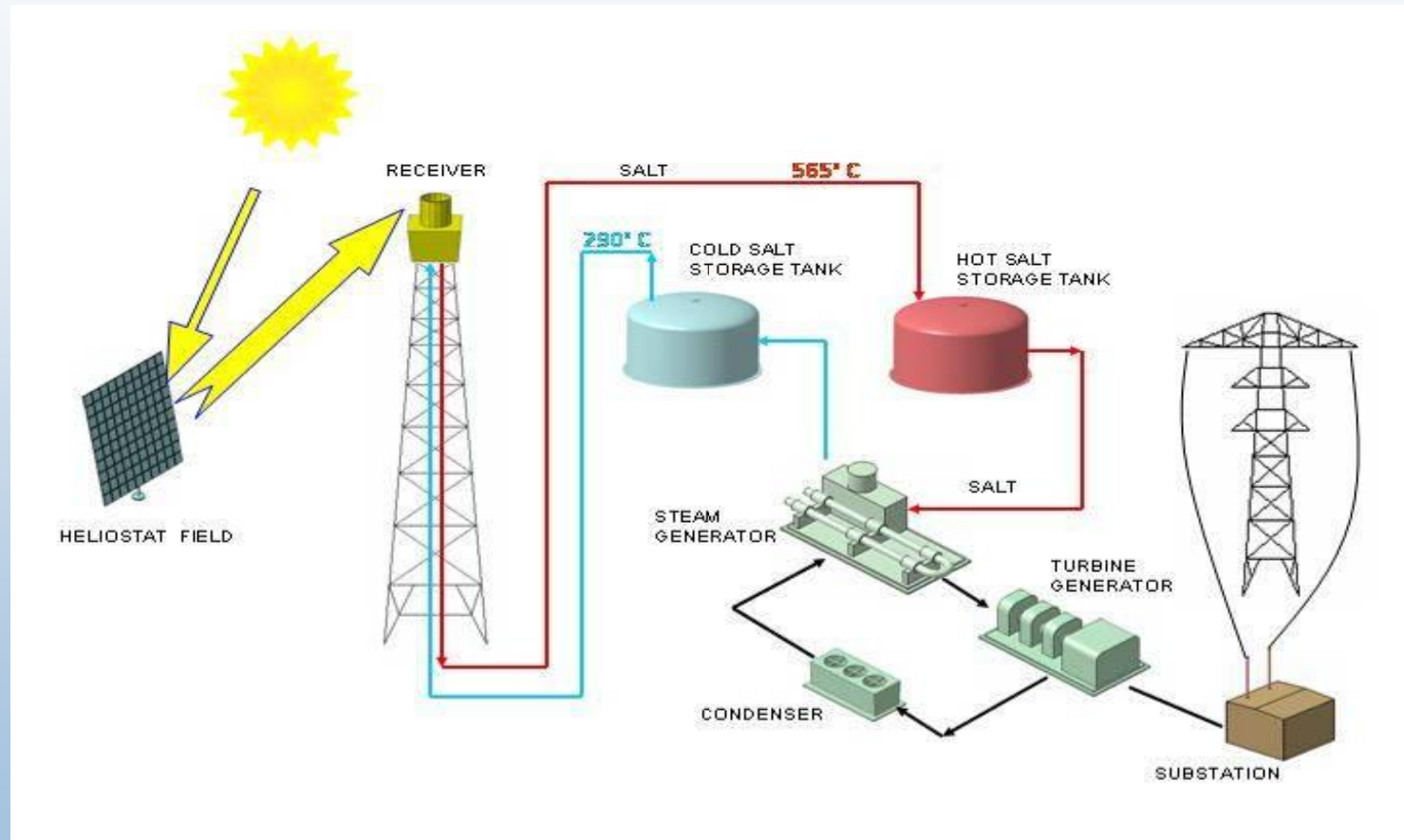


- Over 100% capacity with fossil backup
- Averaged 80% on-peak capacity factor from solar
- Could approach 100% from solar with the addition of thermal energy storage.

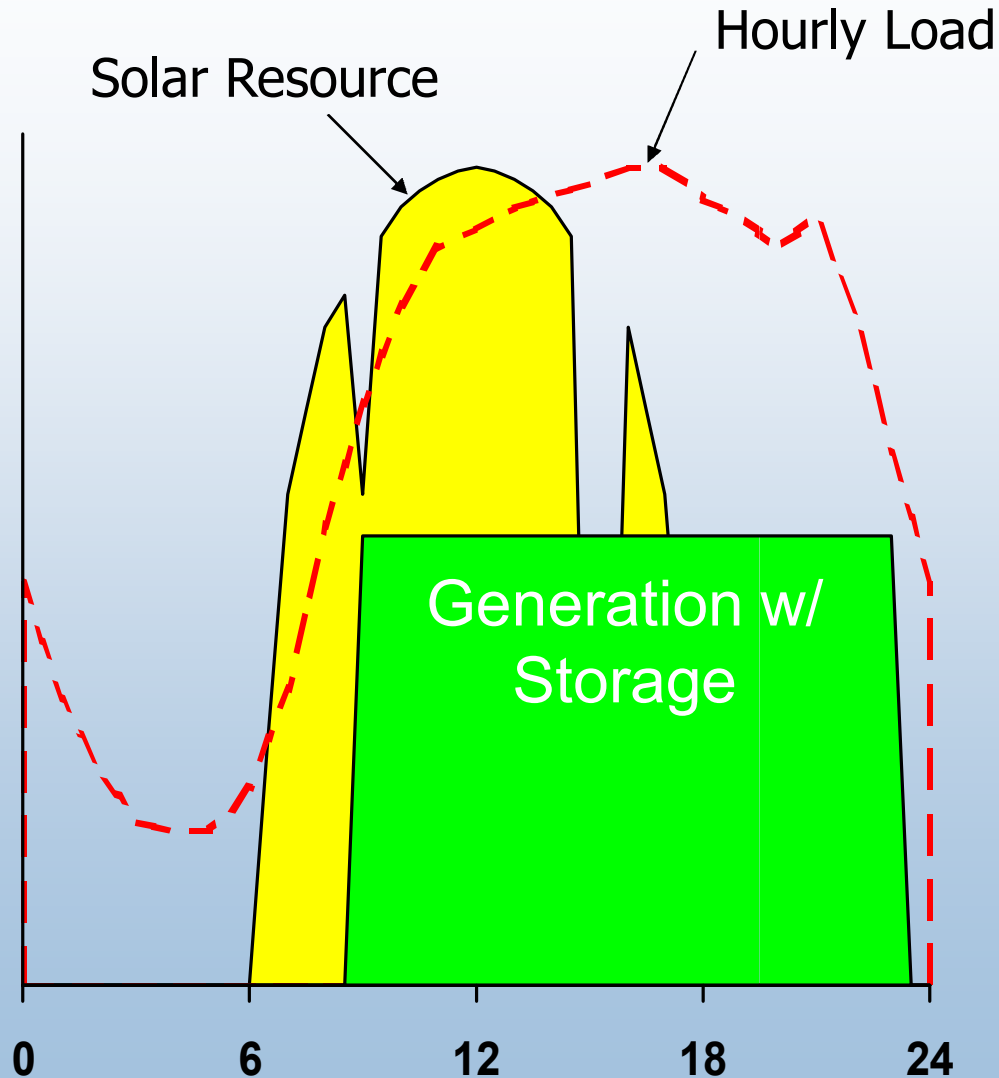
SCE Summer On-Peak
Weekdays: Jun - Sep
12 noon - 6 pm

Source: KJC Operating Company

Power Tower or “Central Receiver” with Thermal Storage



Value of Dispatchable Power? Meeting Peak Power Demand



- Storage provides
 - decoupling of energy collection and generation
 - lower costs because storage is cheaper than incremental turbine costs
 - higher value because power production can match utility needs

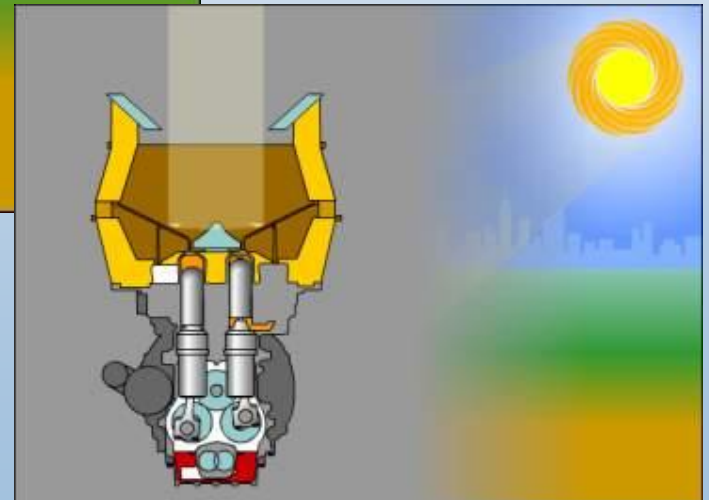
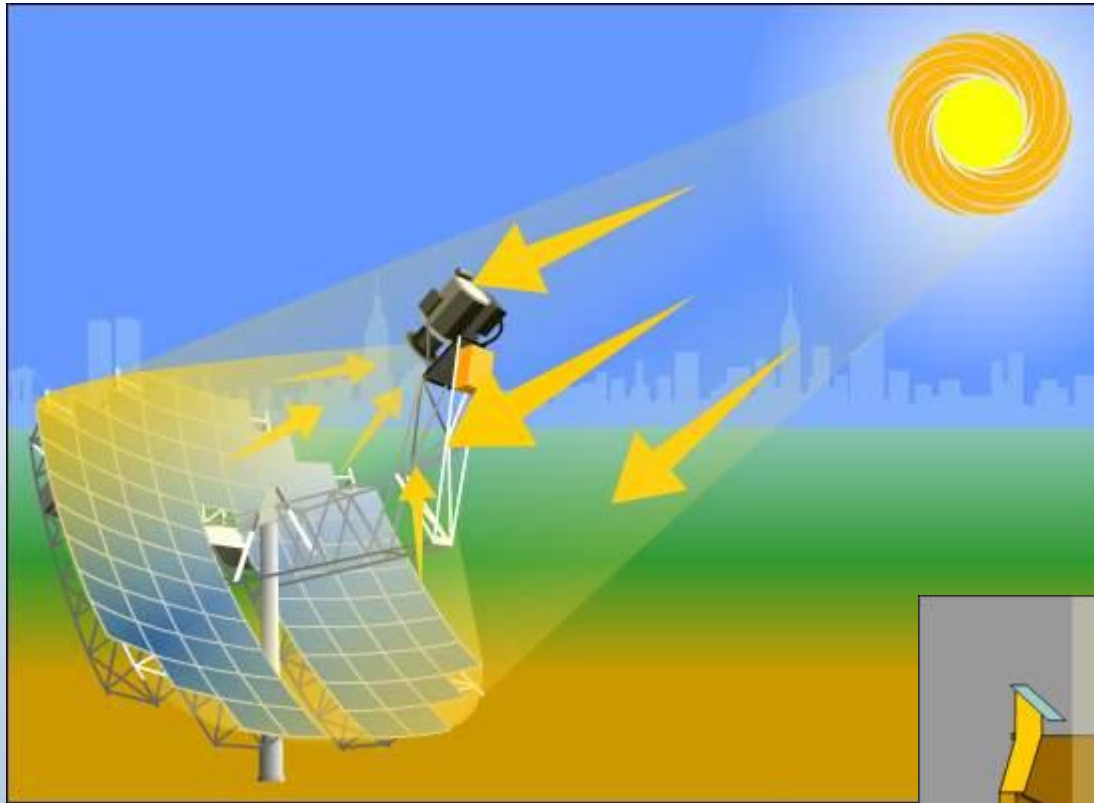
Concentrating Solar Power: Non-Dispatchable Central Station/Distributed Power

- A number of dish and receiver designs have demonstrated high performance (up to 30% solar-to-electric efficiency), but reliability improvement remains a key need
- Domestic and international industry are currently developing systems



- Technology Features:
 - High efficiency
 - Modularity (2-25kW)
 - Thermal-based systems (Stirling engines) can potentially be hybridized w/ fossil fuels.
 - Dish systems can be integrated with high-efficiency PV cells for concentrating PV applications

Dish/Stirling System



6-Dish Prototypes - Sandia



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1-MW Arizona Trough Plant



64 MWe Solargenix Solar Electric Plant: Boulder City, NV

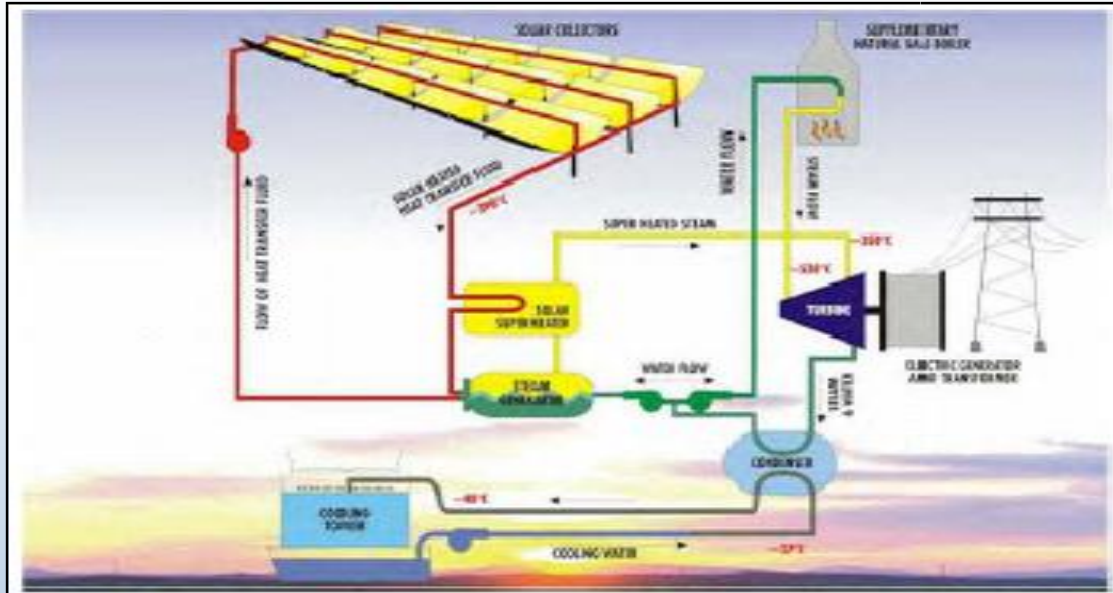






Nevada Solar One

Technical Characteristics



SOLAR FIELD

64 MW solar field – 30 Minutes Storage – No fossil fuel added

Solar Collector Assemblies:	760
Aperture Area (m²/Sq.ft):	5.0 / 59
Length (m/ft):	100/328
Concentration Ratio:	71
Optical Efficiency:	0.77
# of Mirror Segments:	182400
# of receiver tubes	18240
Field Aperture (m²):	357,200
Site area (Km²/acres):	1.42/360
Field Inlet Temp.(°C/°F):	350/662
Field Outlet Temp. (°C/°F):	395/743

- Annual electricity production estimated to be 140 - 150GWh

Turbine Generator Gross Output
Net Output to Utility

75 MWe
70 MWe

Solar Steam Conditions

Inlet Pressure

102 bars/1480 psi

Reheat Pressure

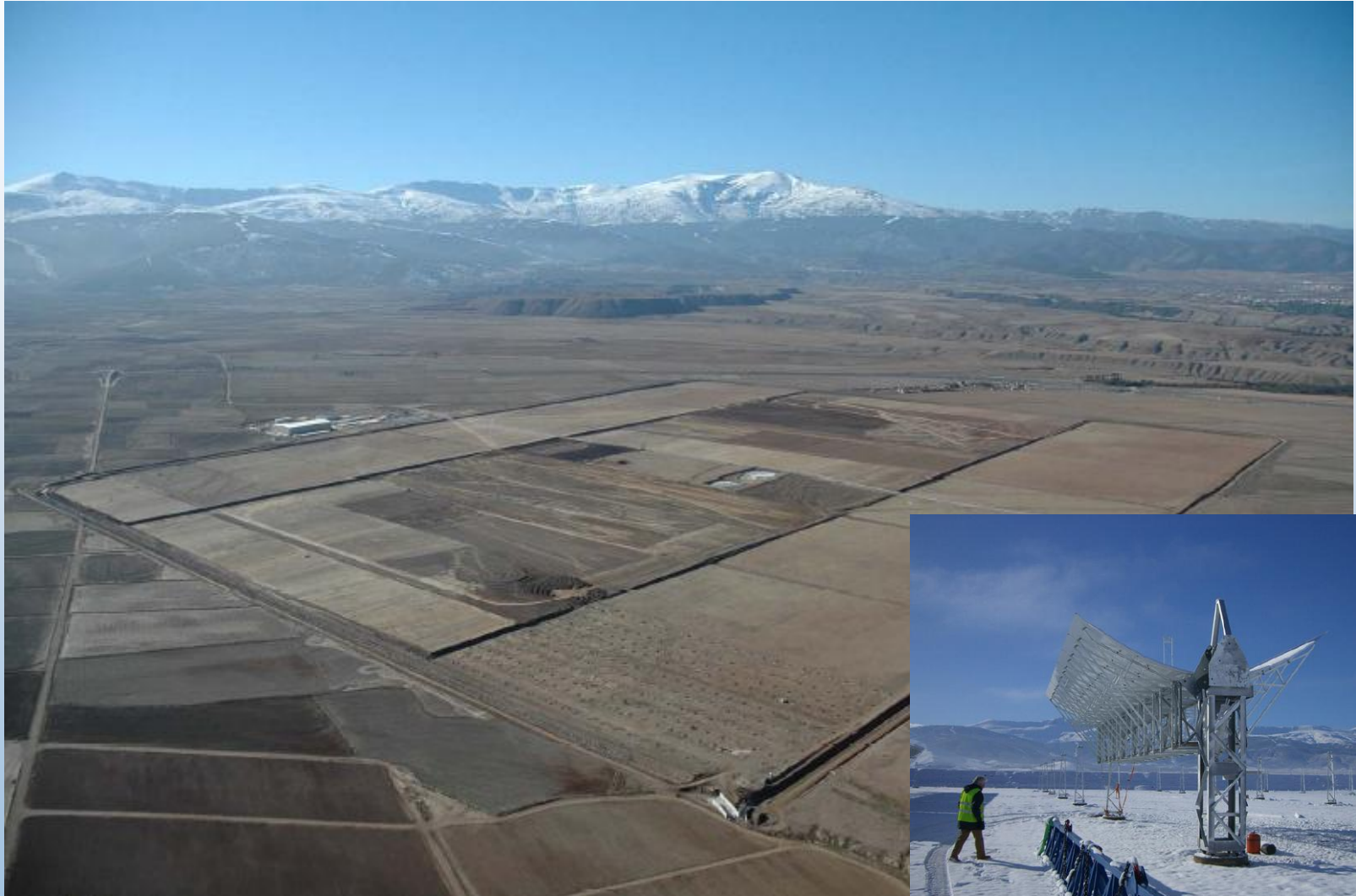
17.5 bars/254 psi

Inlet Temperature

371 Deg.C / 700 Deg.F

AndaSol-1

Andalucia, Spain



Solucar PS10 Sevilla, Spain



U.S. and International Market Opportunities

CSP Plants Under Construction or nearing financial closure:

- USA: 1 MW parabolic trough plant
 - Organic Rankine turbine integrated w/ conventional solar field
 - Solar only but constructed w/ consideration for future thermal storage
- USA: 64 MW capacity solar-only parabolic trough plant – 2006 construction start, on-grid June, 2007
 - Solar only plant (allowance for small percentage of gas)
 - SolarGenix/Acciona collector, Schott and Solel HCEs
- Spain: 3x50 MW capacity solar parabolic trough plants
 - Andasol 1: under construction
 - Andasol 2: fully permitted and financed
 - 7.5 hours of indirect 2-tank molten salt storage
 - Solar Millennium collector, Schott HCEs
- Spain: 11MW PS10 tower
 - Steam receiver and turbine w/ 1 hour thermal storage (1/2 load)
 - Startup in November, 2006
 - PS20 (20MW saturated steam plant) under construction

U.S. and International Market Opportunities

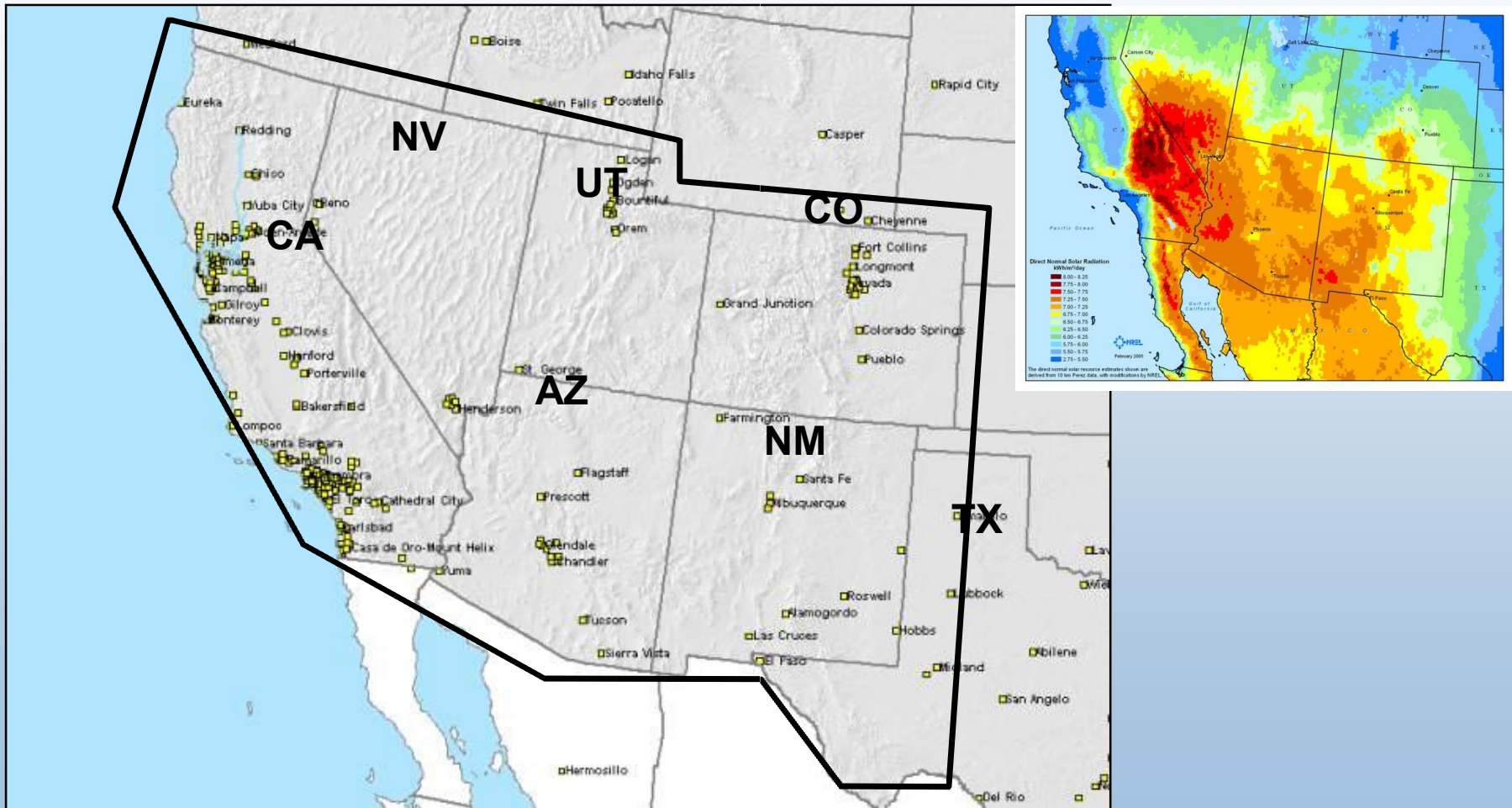
CSP Plants in Development Stage:

- Spain: Spanish government likely to raise 2010 target from 200MW to 500MW of CSP
 - 2GWs of CSP in planning stages
- USA: SES PPAs signed with SCE and SDG&E for at least 800MW of dish/Stirling systems (up to 1.7 GW)
- Algeria: Abener approved to supply 30MW solar field for integration into a 140 MW Integrated Solar Combined Cycle (ISCC) parabolic trough plant
- Australia: 1MW thermal compact line focus receiver (CLFR) array (stand alone). 5MW thermal system integrated with coal station feedwater heaters under construction.
- Israel: Solel issued contract for 150 MW capacity hybrid solar parabolic trough plant.
- Mexico: RFP issued for integration of 30MW solar field for integration into 300 MW ISCC plant
- Egypt: 127 MW ISCC plant with 29 MW solar capacity
- Morocco: 230 MW ISCC plant with 35 MW solar capacity.
- India: 140 MW ISCC plant with 35 MW solar capacity.
- Greece: 50 MW capacity parabolic trough plant based on new Greek feed-in tariff

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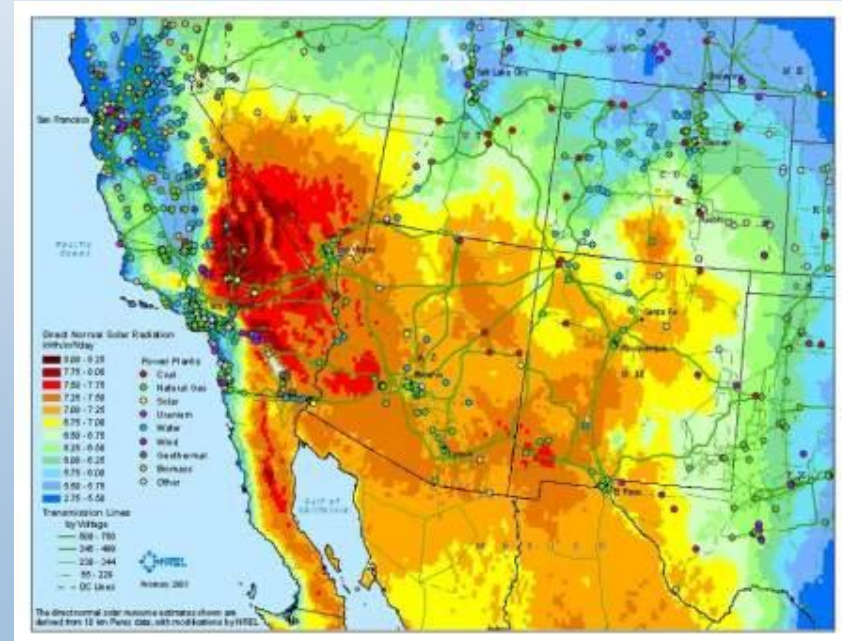
1000MW Analysis Focused on the Southwest Region



U.S. Southwest GIS Screening Analysis for CSP Generation

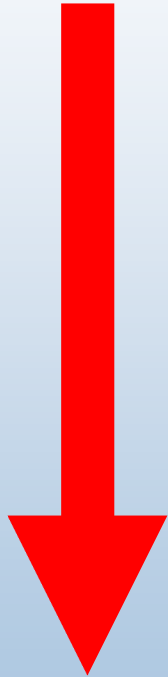
Screening Approach

- Initial GIS screening analysis used to identify regions most economically favorable to construction of large-scale CSP systems.
- GIS analysis used in conjunction with transmission and market analysis to identify favorable regions in four southwest states.



Southwest Solar Resources: Which Locations Are Suitable for CSP Development?

All Solar Resources

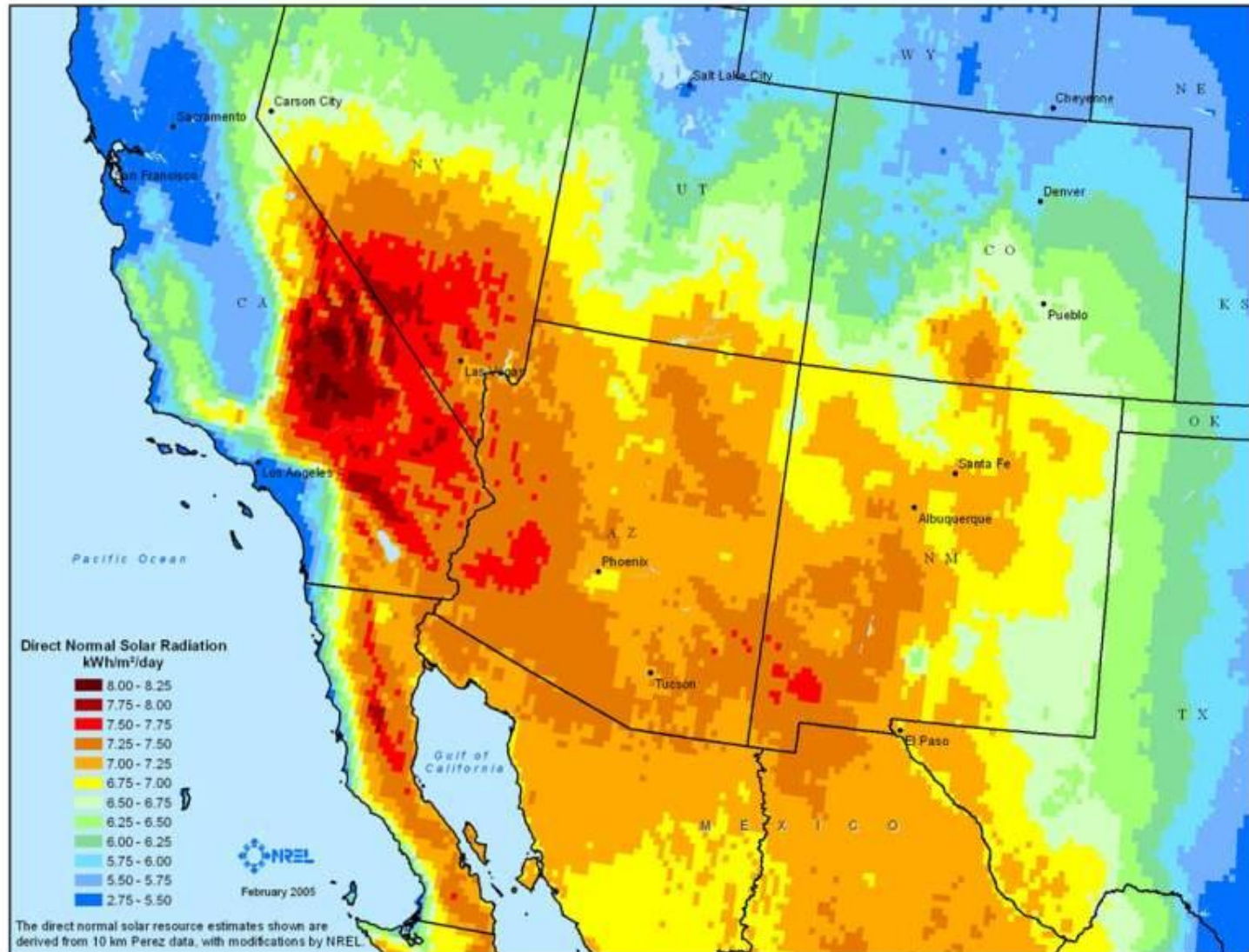


Locations Suitable for
Development

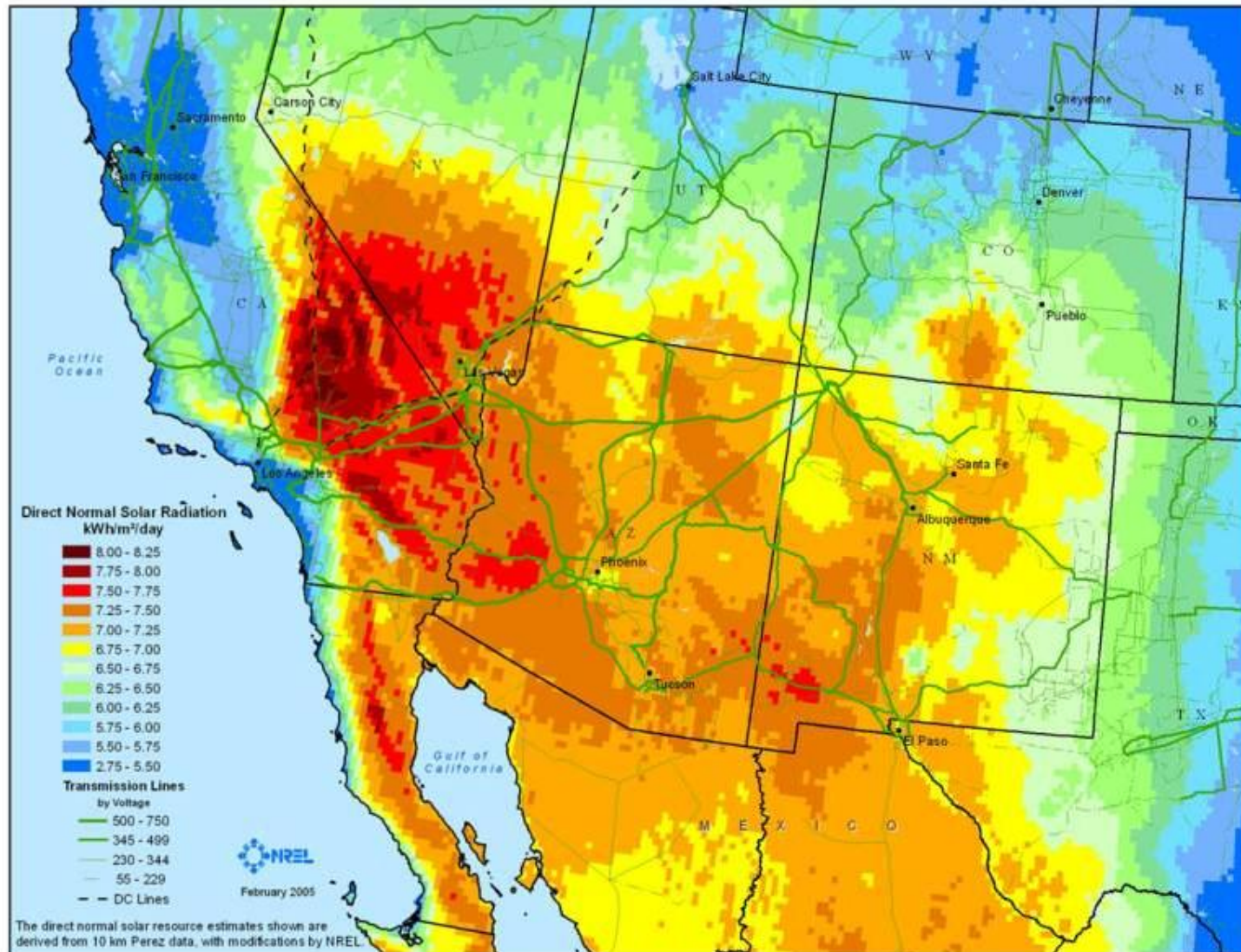
1. Start with direct normal solar resource estimates derived from 10 km satellite data.
2. Eliminate locations with less than 6.75 kwh/m²/day.
3. Exclude environmentally sensitive lands, major urban areas, and water features.
4. Remove land areas with greater than 1% (and 3%) average land slope.
5. Eliminate areas with a minimum contiguous area of less than 5 square kilometers.

Southwest Solar Resources

Unfiltered Data

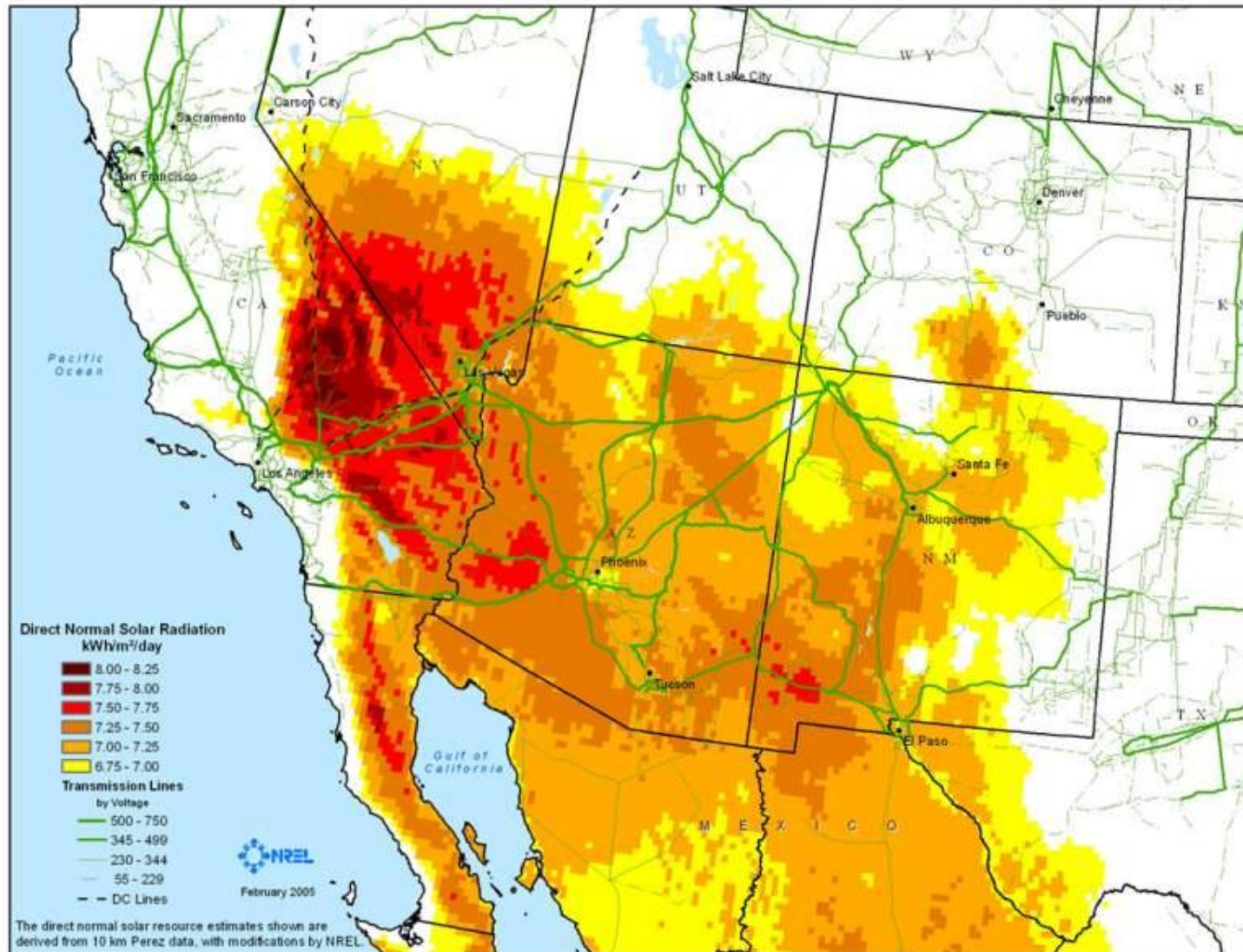


Southwest Solar Resources Transmission Overlay



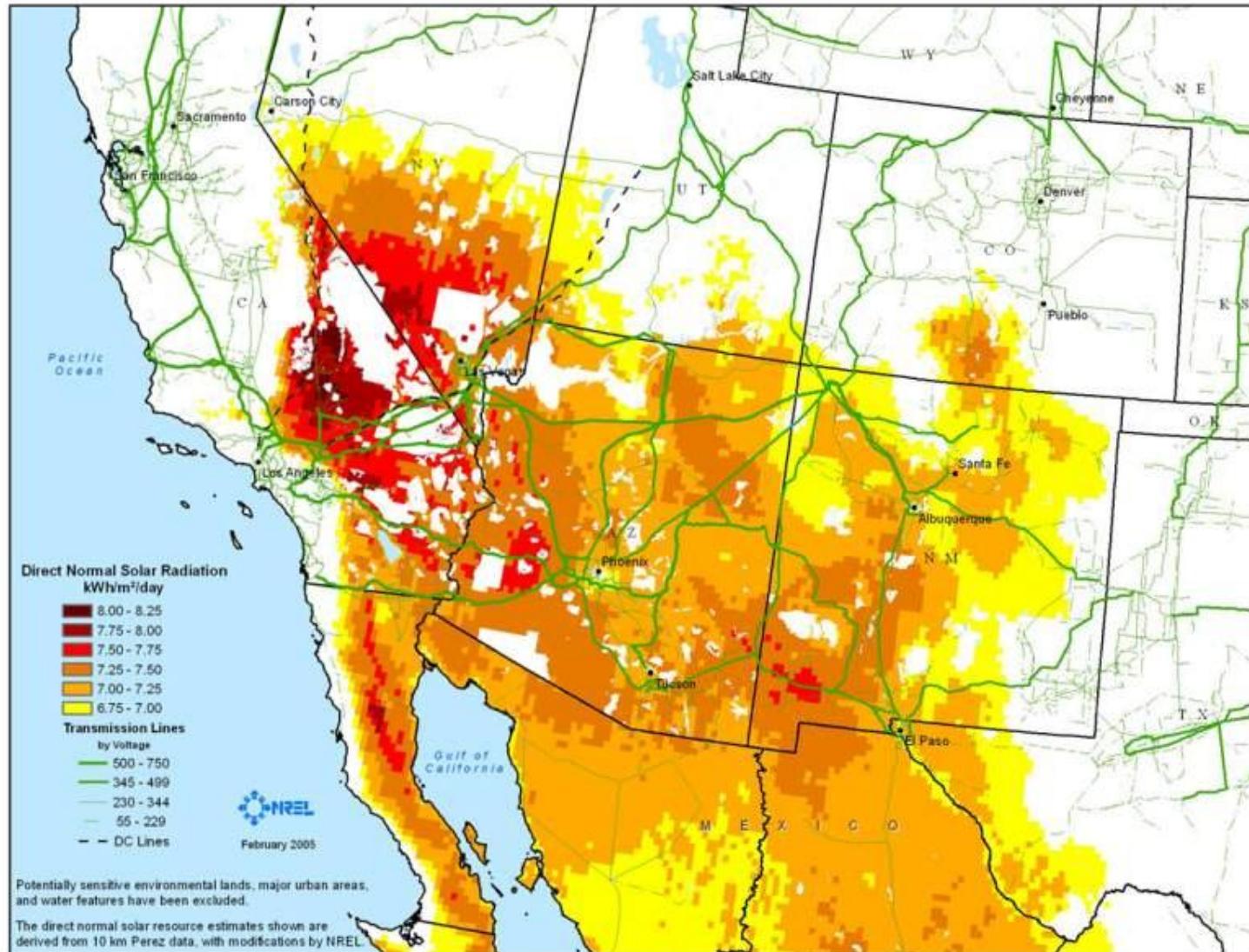
Southwest Solar Resources

> 6.75 kWh/m²/day



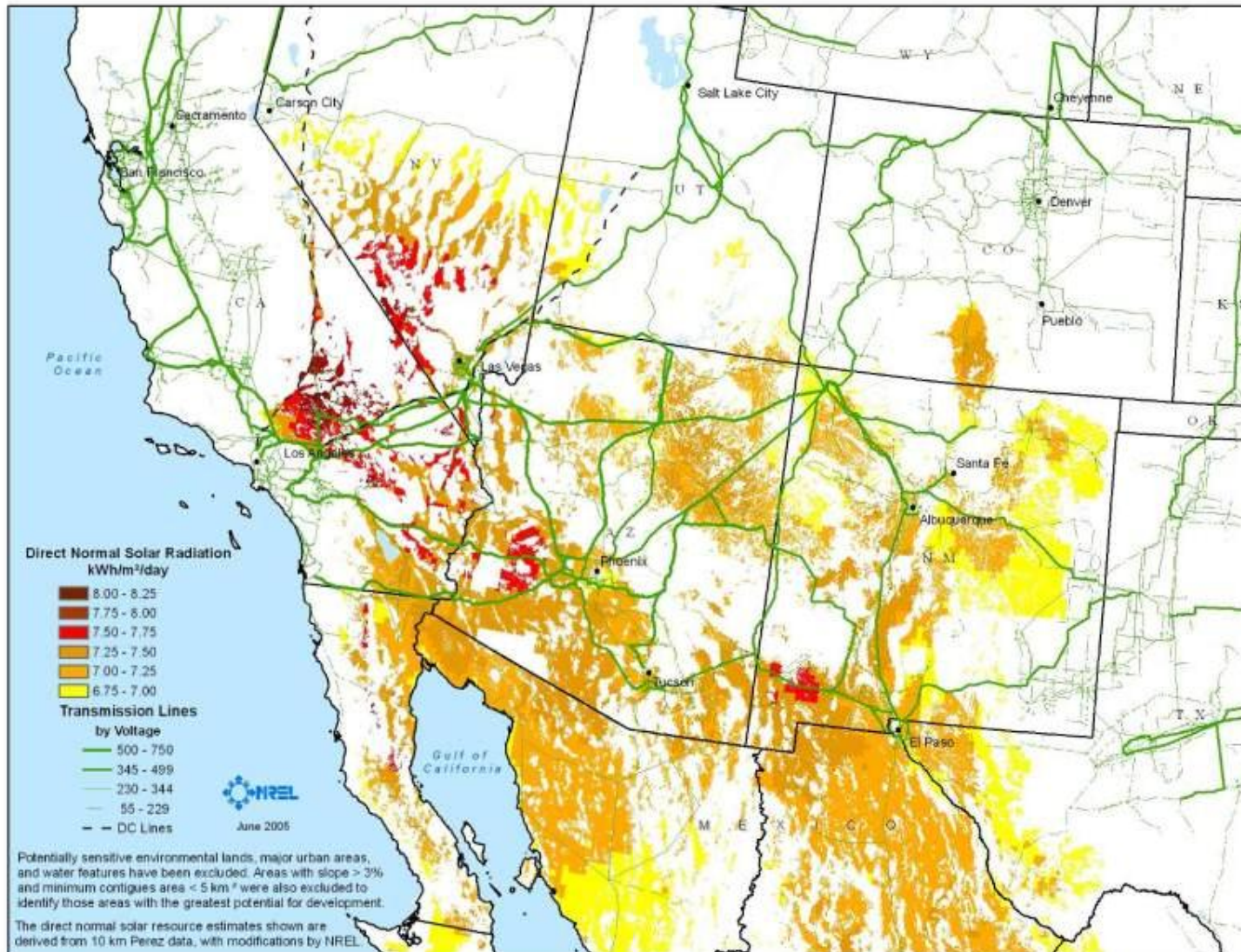
Southwest Solar Resources

Prior plus Environmental and Land Use Exclusions

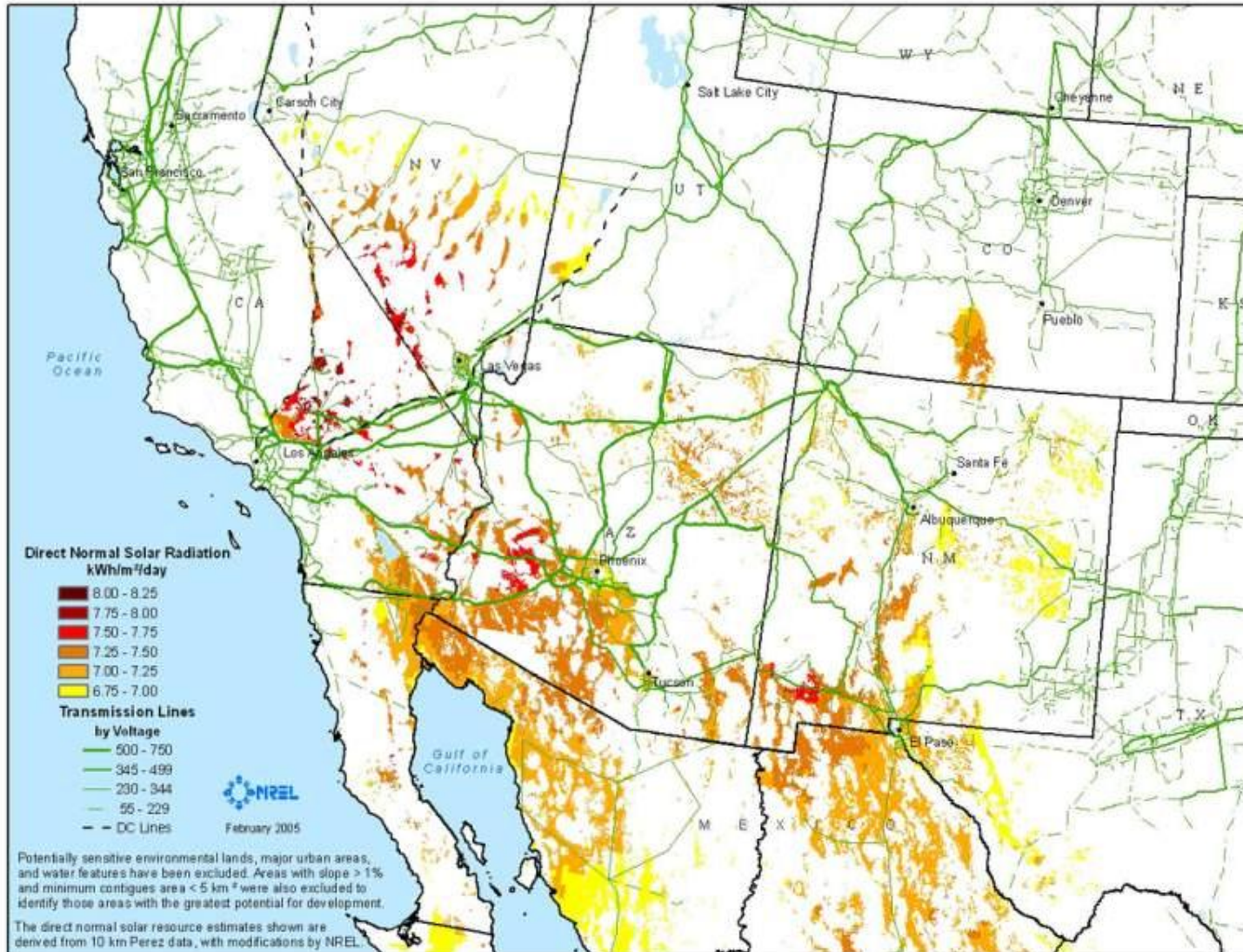


Southwest Solar Resources

Prior plus Slope < 3%



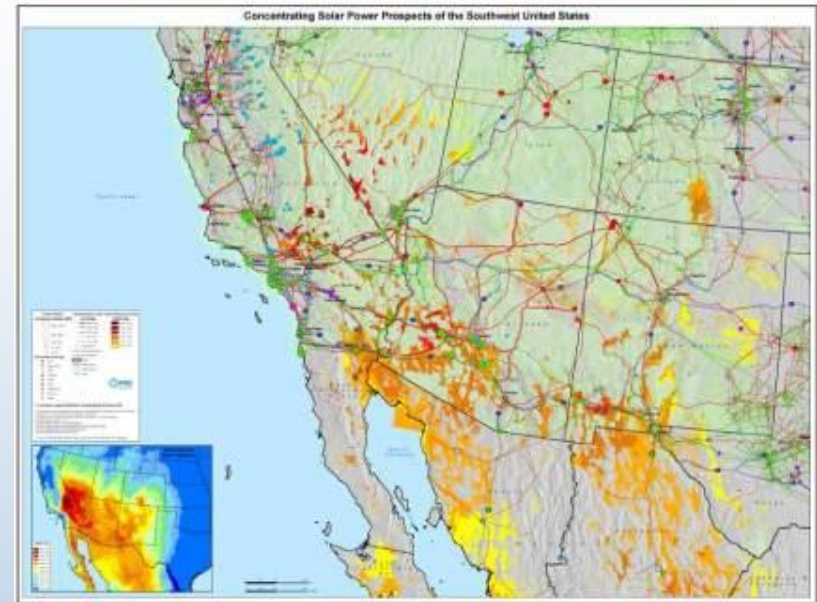
Prior plus Slope < 1%



Energy Benefits

Southwest Solar Energy Potential

State	Land Area (mi ²)	Solar Capacity (MW)	Solar Generation Capacity GWh
AZ	19,279	2,467,663	5,836,517
CA	6,853	877,204	2,074,763
CO	2,124	271,903	643,105
NV	5,589	715,438	1,692,154
NM	15,156	1,939,970	4,588,417
TX	1,162	148,729	351,774
UT	3,564	456,147	1,078,879
Total	53,727	6,877,055	16,265,611



The table and map represent land that has no primary use today, exclude land with slope > 1%, and do not count sensitive lands.

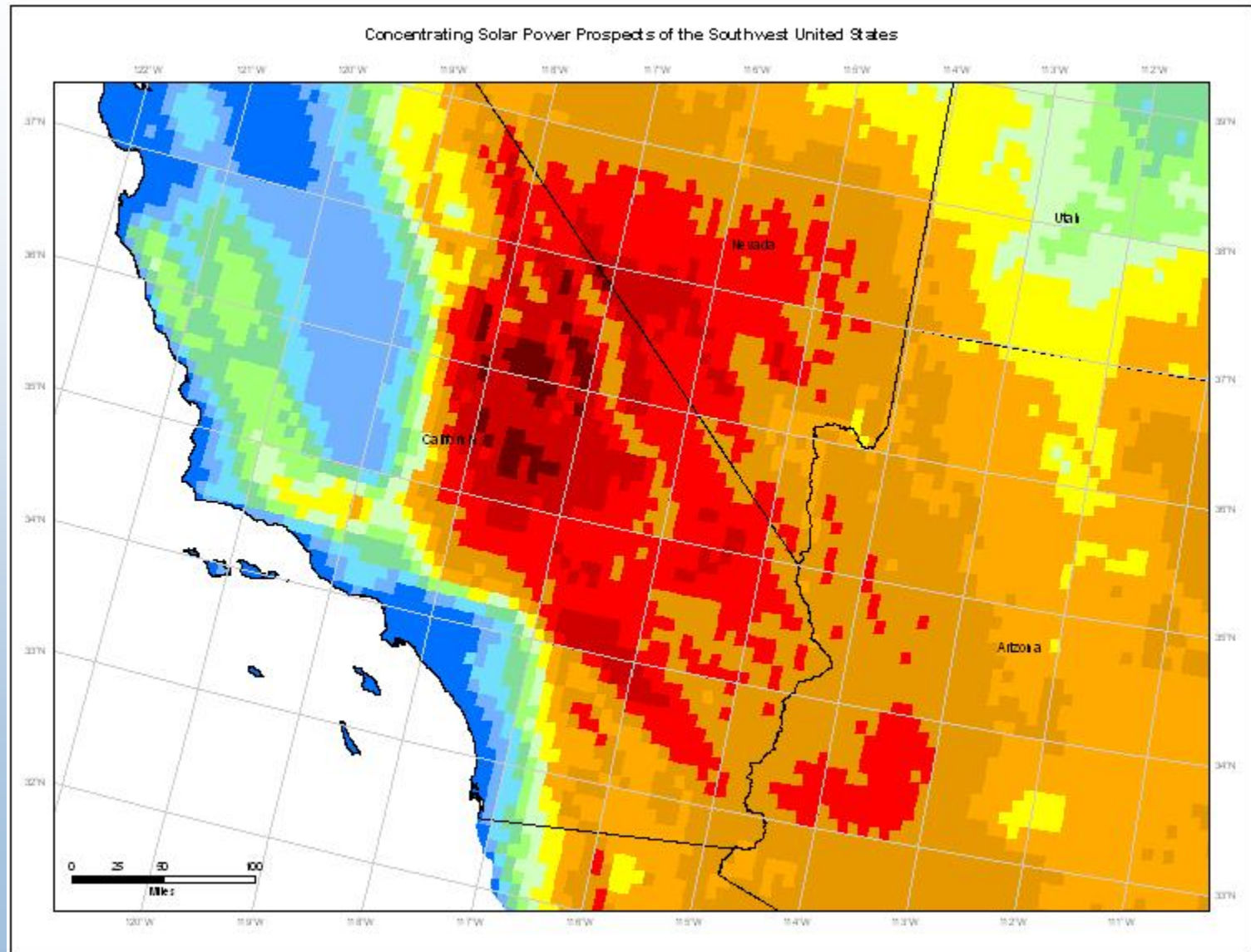
Solar Energy Resource ≥ 6.75

Capacity assumes 5 acres/MW

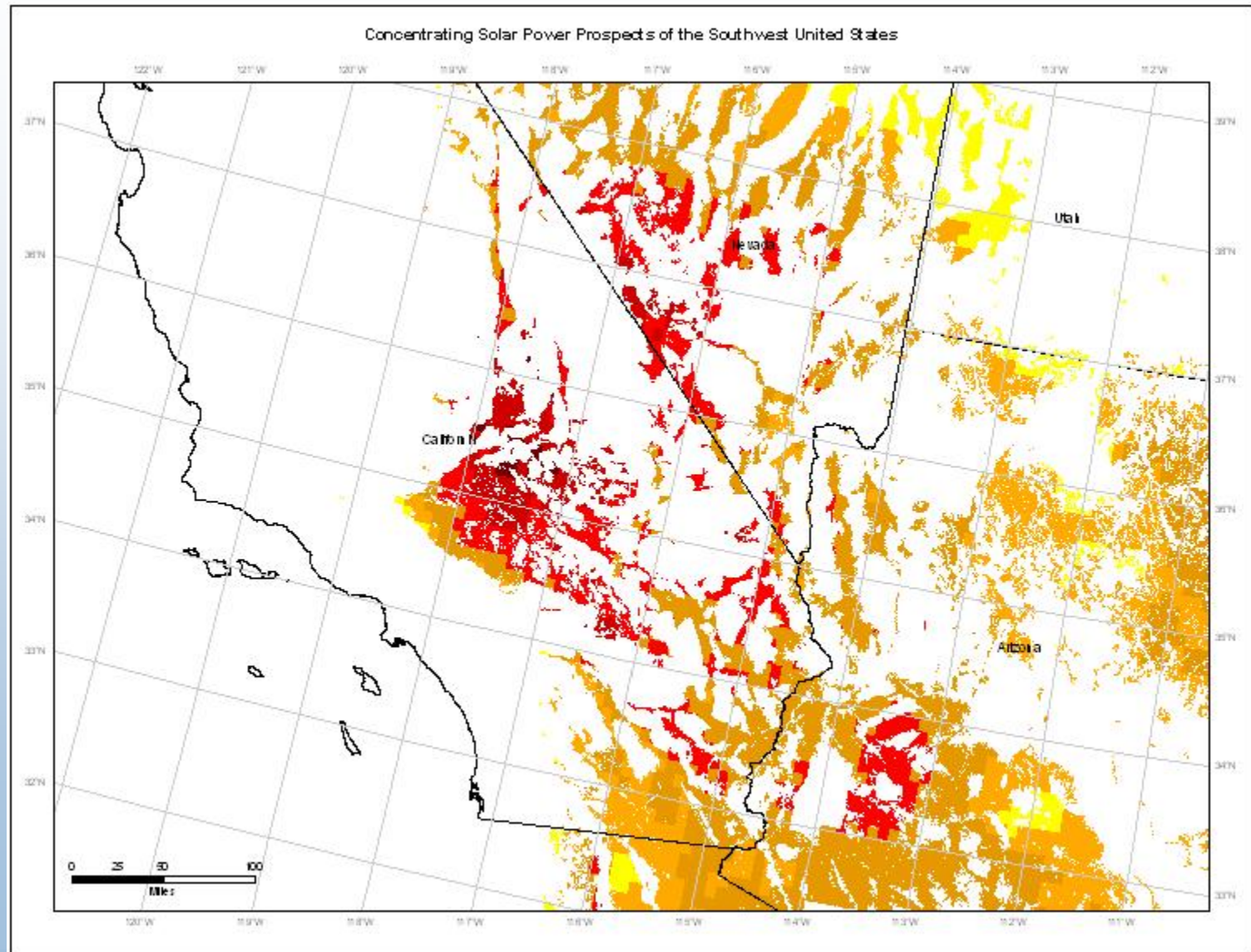
Generation assumes 27% annual capacity factor

- Current total generation in the U.S. is 1,000GW w/ generation approximately 3,800 TWh

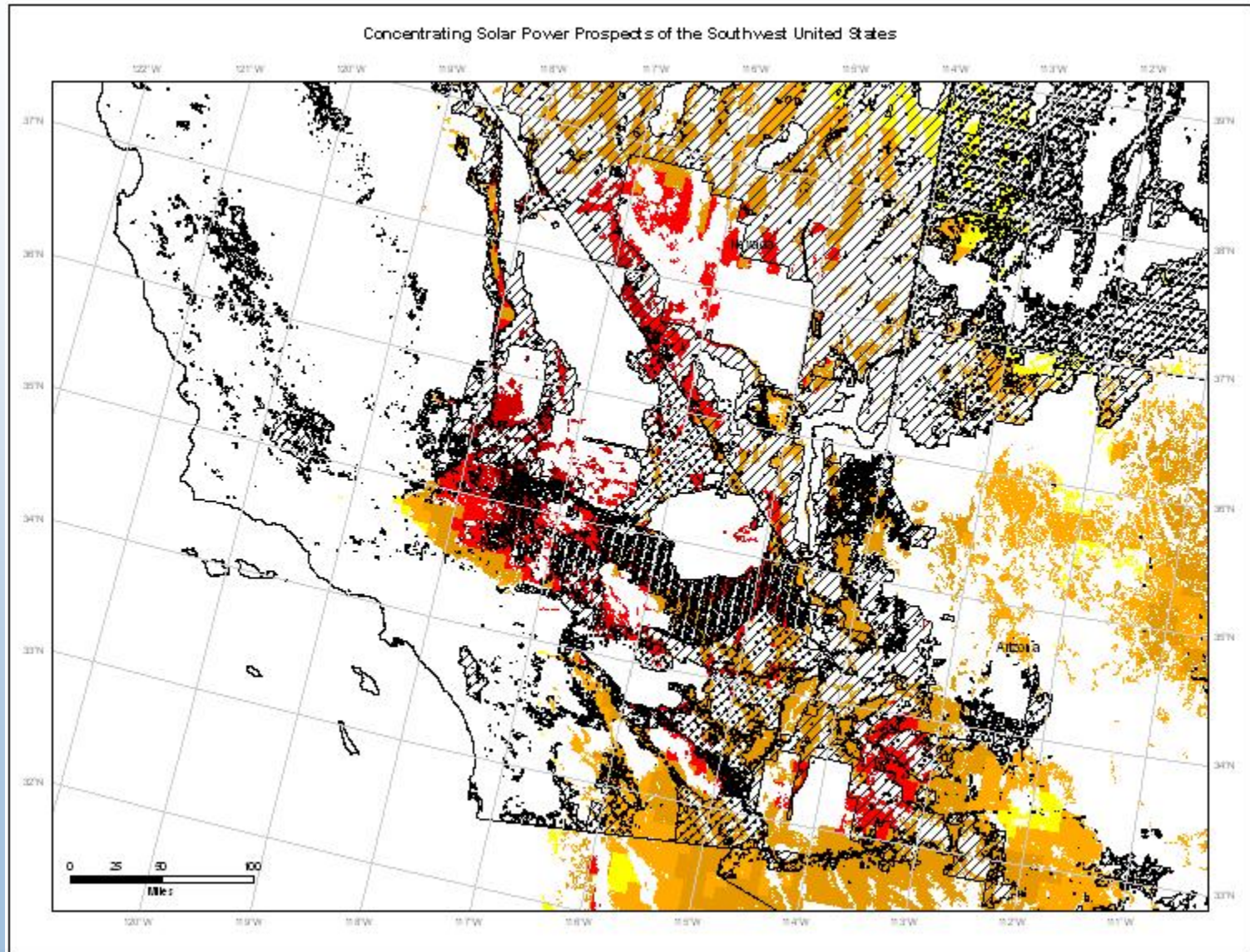
CSP on Federal Lands – Unfiltered Resource



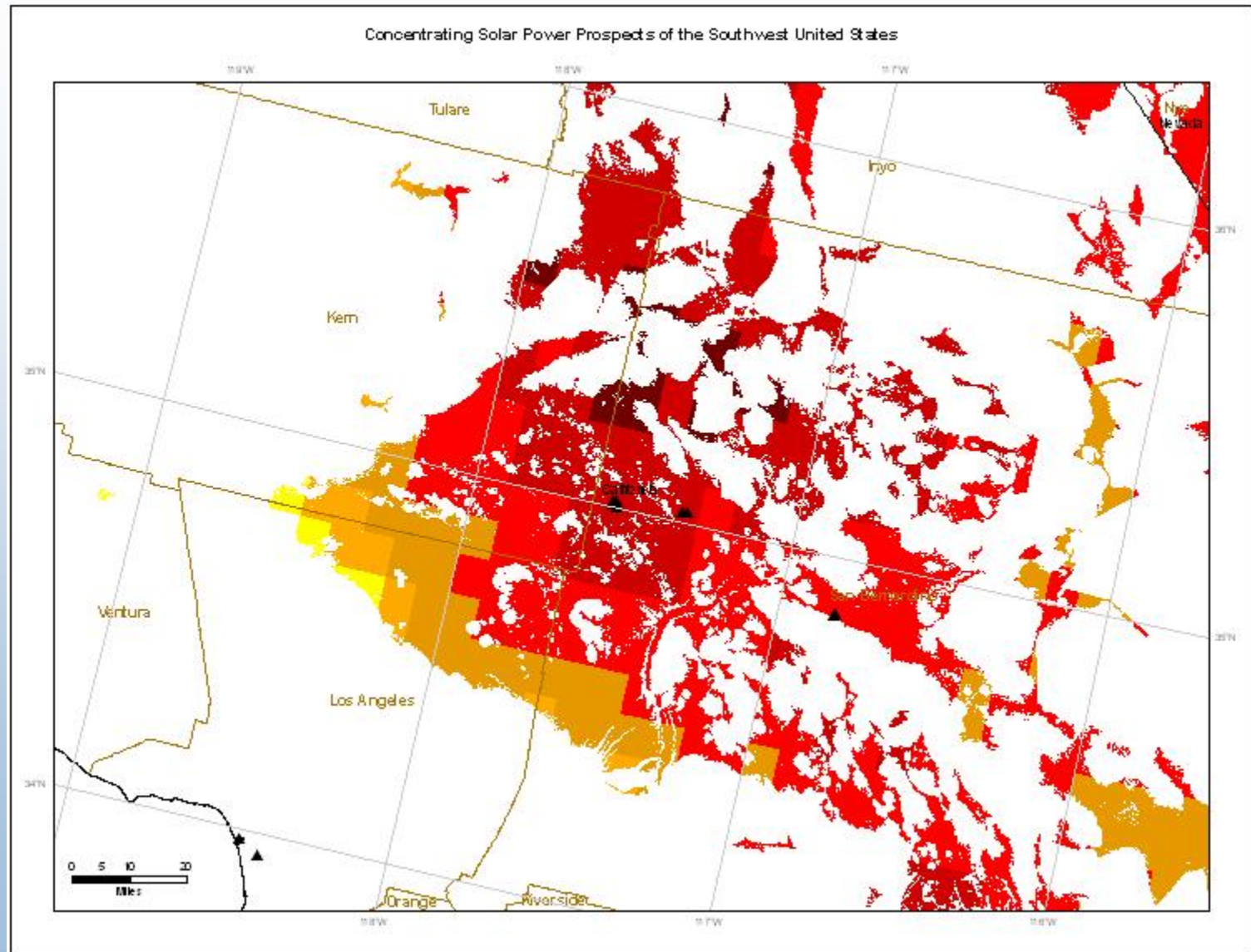
CSP on Federal Lands – Filtered Resource



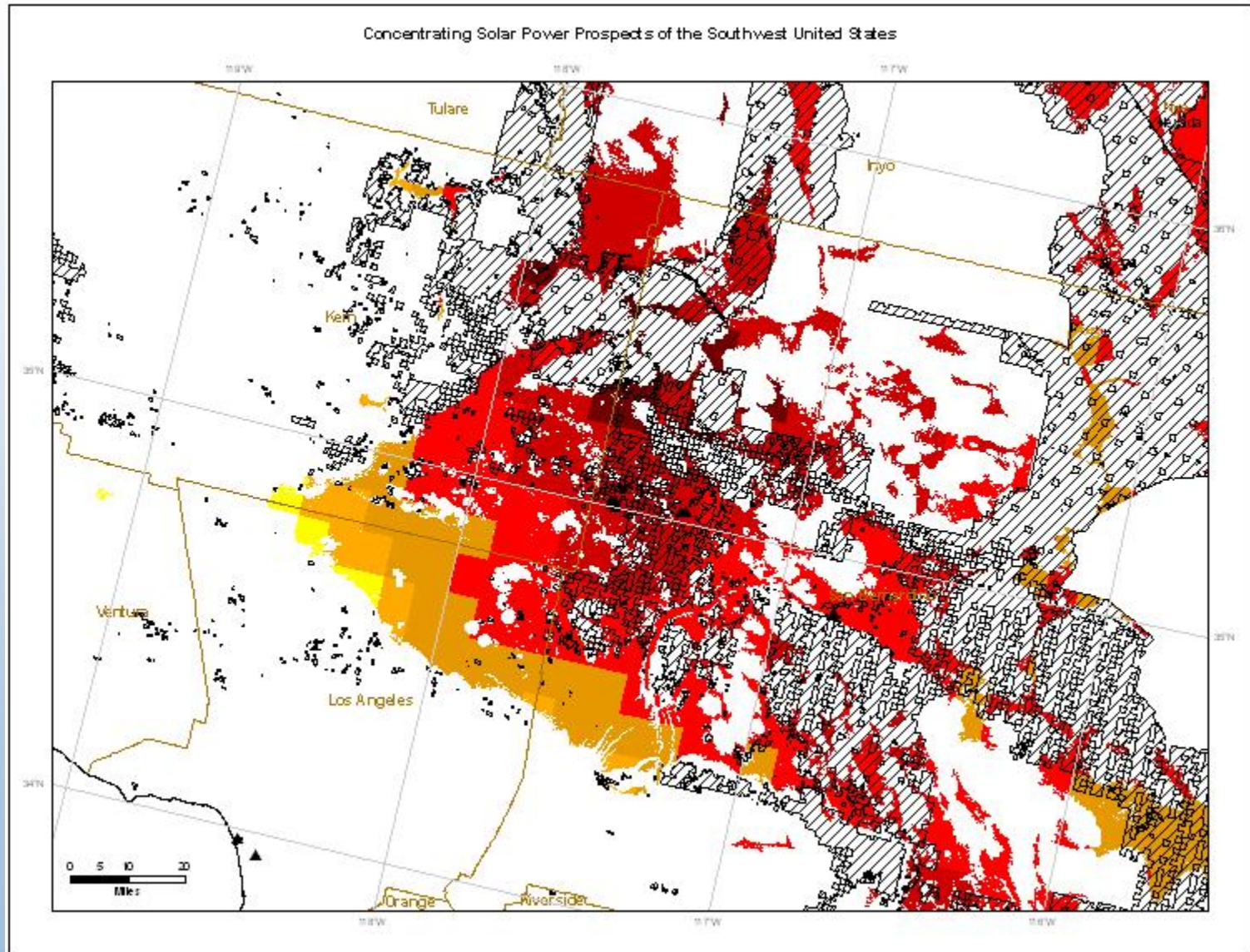
CSP on Federal Lands – BLM Territory



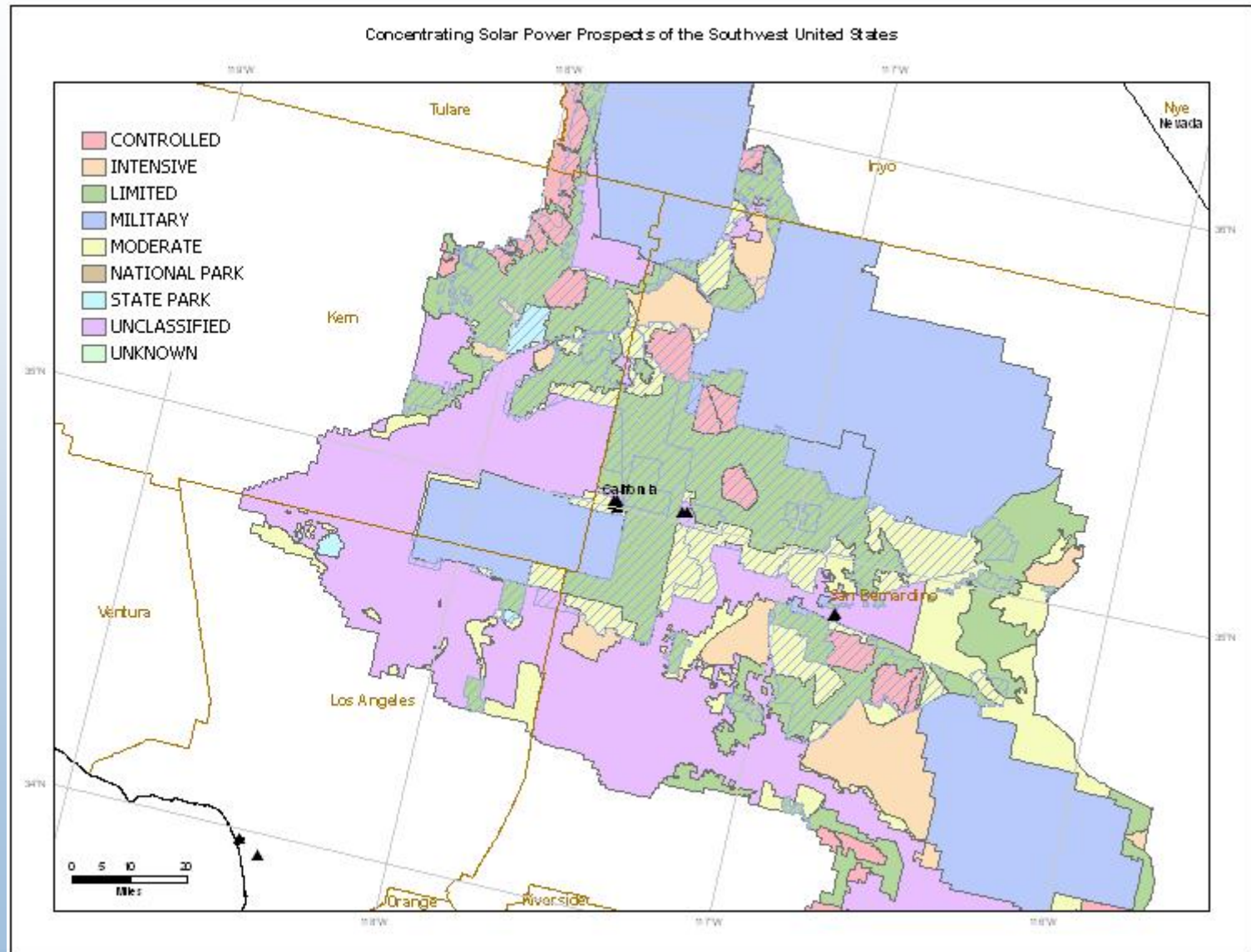
Mojave Desert Region



Mojave Desert Region – BLM Territory



West Mojave Plan



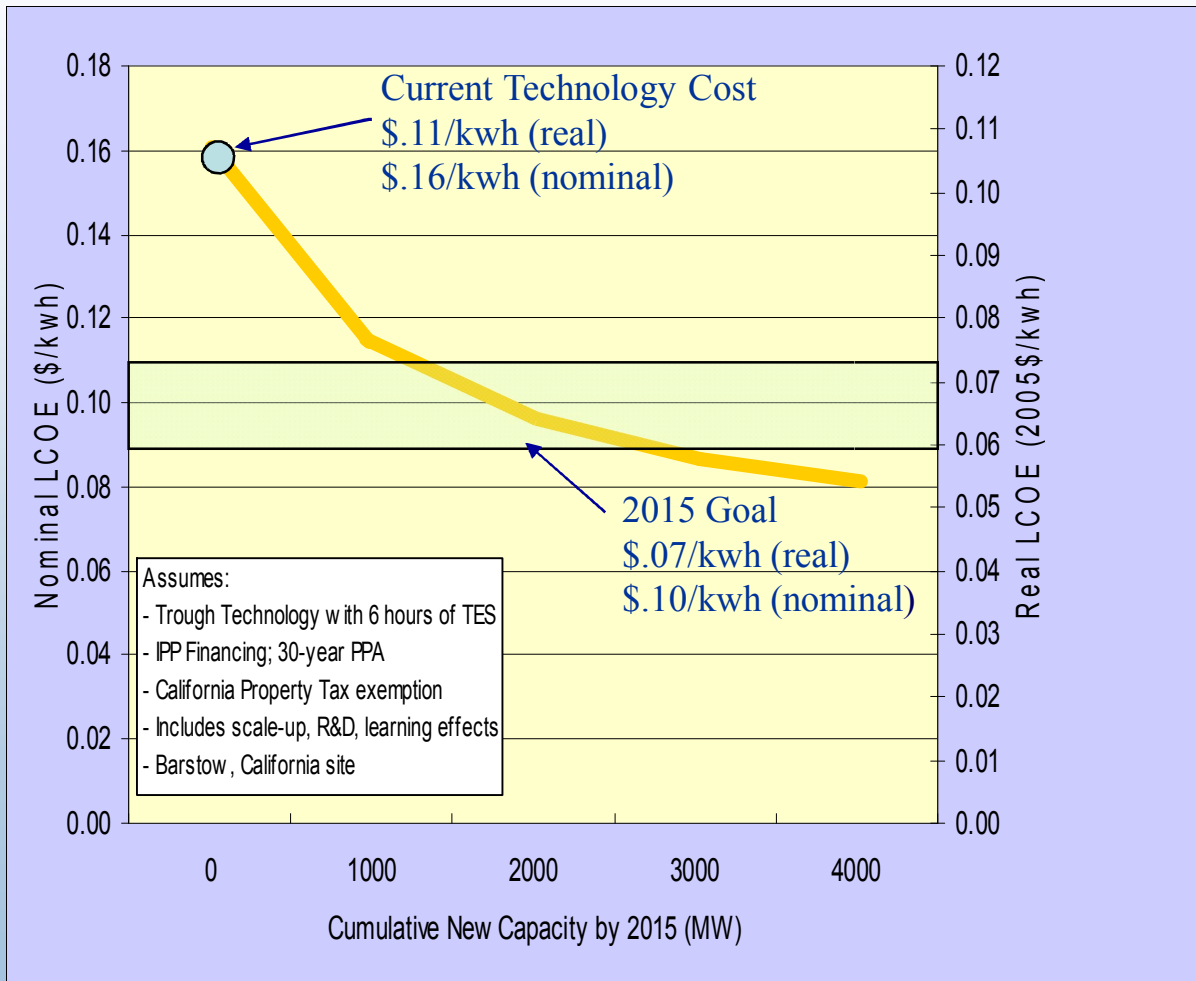
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What is Central Solar Power Worth?

- WGA Solar Task Force used the California Energy Commission (CEC) methodology as a proxy for the value of power from conventional generation
- California Renewable Portfolio Standard (RPS) currently calls for 20% of state's generation to come from renewables by 2017 (considering increasing to 33% by 2020)
- Methodology uses a “Least Cost, Best Fit” Criteria
- The Market Price Referent (MPR) is calculated as the value of displaced conventional generation

Bridging the Cost Gap



Cost Reductions to Bridge the Gap

- Deployment
- Plant Size
- Financing
- R&D

Analysis does not include current 30% investment tax credit

Source: WGA Solar Task Force Summary Report

Questions?

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